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CHAPTER 1 Introduction

1.1 Background

Post, Buckley, Schuh & Jernigan, Inc. contracted ADS Environmental Services to conduct flow monitoring at eight (8) locations in the City of Chula Vista, CA sanitary sewage collection system. The objective of this study was to measure depth and velocity and to quantify flows.

1.2 Project Scope

The scope of this study involved using temporary flow monitors to quantify wastewater flow at eight (8) locations in the City of Chula Vista, CA for fourteen (14) consecutive days. Specifically, the study included the following key components.

- Investigate the proposed flow-monitoring sites for adequate hydraulic conditions.
- Flow monitor installations.
- Flow monitor confirmations and data collections.
- Flow data analysis.

CHAPTER 2 Equipment and Methodology

2.1 Flow Quantification Methods

There are two main equations used to measure open channel flow; the Continuity Equation and the Manning Equation. The Continuity Equation, which is considered the most accurate, can be used if both depth of flow and velocity are available. The Manning Equation only requires depth of flow and certain physical characteristics of the pipe. The Manning Equation can be used, where applicable, to corroborate or support the interpretation of results obtained from the Continuity Equation, and in certain cases, can be used to estimate velocity data in the event of sensor obstruction or failure. A more detailed discussion of each equation follows.

2.1.1 Continuity Equation

The Continuity Equation states that the flow quantity (Q) is equal to the wetted area (A) multiplied by the average velocity (V) of the flow.

$$Q = A * V$$

This equation is applicable in a variety of conditions including backwater, surcharge, and reverse flow. Most modern flow monitoring equipment, including the ADS Models, measure both depth and velocity and therefore use the Continuity Equation to calculate flow quantities.

2.1.2 Manning Equation

The Manning Equation states the following:

$$Q = 1.486 * A * Rh^{2/3} * s^{1/2} / n$$

Where,

Q = flow quantity

A = wetted area

s = slope of the hydraulic grade line (ideally equal to slope of pipe)

n = roughness factor for the pipe

Rh = hydraulic radius (wetted area / wetted perimeter)

Values of s and n can be approximated using "As Built" drawings or an equivalent ratio developed through a series of field confirmations.

Although the Manning Equation has been a traditional method of flow quantification, it is applicable only during uniform, steady flow conditions. Therefore, the Manning Equation is not suitable for sites that experience backwater, surcharge, or other varied unsteady flow conditions.

2.2 Flow Monitoring Equipment

The monitor selected for this project was the ADS Model 1500-flow monitor. This flow monitor is an area velocity flow monitor that uses both the Continuity and Manning's equations to measure flow.

The ADS Model 1500-flow monitor consists of data acquisition sensors and a battery-powered microcomputer. The microcomputer includes a processor unit, data storage, and an on-board clock to control and synchronize the sensor recordings. The monitor was programmed to acquire and store depth of flow and velocity readings at 15-minute intervals. A laptop computer was used in the field to retrieve and store data from the monitor.

Three types of data acquisition sensors are available for Model 1500 flow monitor. The primary depth measurement device is the ADS quad-redundant ultrasonic level sensor. This sensor uses four independent ultrasonic transceivers in pairs to measure the distance from the face of the transceiver housing to the water surface (air range) with up to four transceiver pairs, of the available one, active at one time. The elapsed time between transmitting and receiving the ultrasonic waves is used to calculate the air range between the sensor and flow surface based on the speed of sound in air. Sensors in the transceiver

housing measure temperature, which is used to compensate the ultrasonic signal travel time. The speed of sound will vary with temperature. Since the ultrasonic level sensor is mounted out of the flow, it creates no disturbance to normal flow patterns and does not affect site hydraulics.

Redundant flow depth data can be provided by a pressure depth sensor, and is independent from the ultrasonic level sensor. This sensor uses a piezo-resistive crystal to determine the difference between hydrostatic and atmospheric pressure. The pressure sensor is temperature compensated and vented to the atmosphere through a desiccant filled breather tube. Pressure depth sensors are typically used in larger size channels and applications where surcharging is anticipated. Its streamlined shape minimizes flow distortion.

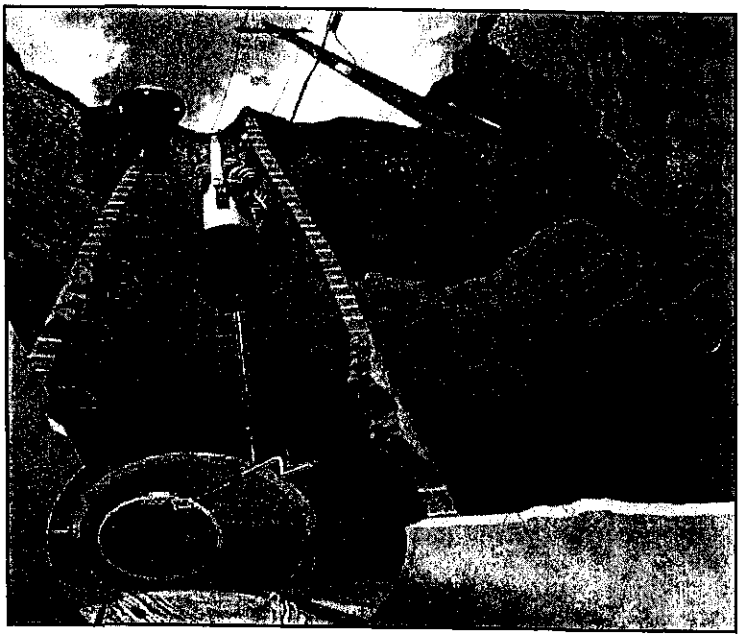
Velocity is measured using the ADS V-3 digital Doppler velocity sensor. This sensor measures velocity in the cross-sectional area of flow. An ultrasonic carrier is transmitted upstream into the flow, and is reflected by suspended particles, air bubbles, or organic matter with a frequency shift proportional to the velocity of the reflecting objects. The reflected signal is received by the sensor and processed using digital spectrum analysis to determine the peak flow velocity. Collected peak velocity information is filtered and processed using field confirmation information and proprietary software to determine the average velocity, which is used to calculate flow quantities. The sensor's small profile, measuring 1.5 inches by 1.15 inches by 0.50 inches thick, minimizes the affects on flow patterns and site hydraulics.

2.3 Installation

Installation of flow monitoring equipment typically proceeds in four steps. First, the site is investigated for safety and to determine physical and hydraulic suitability for the flow monitoring equipment. Second, the equipment is physically installed at the selected location. Third, the monitor is tested to assure proper operation of the velocity and depth of flow sensors and verify that the monitor clock is operational and synchronized to the master computer clock. Fourth, the depth and velocity sensors are confirmed and line confirmations are performed. A typical Model 1500 flow monitor installation is shown in Figure 2.1.

The installation presented in Figure 2.1 is typical for circular or oval pipes up to approximately 42-inches in diameter or height. In this type of installation, depth and velocity sensors are mounted on an expandable ring and installed one to two pipe diameters upstream of the pipe/manhole connection in the incoming sewer pipe. This reduces the affects of turbulence and backwater caused by the connection. This type of installation was used on this project.

Figure 2.1 Typical Installation



2.4 Data Collection, Confirmation, and Quality Assurance

During the monitoring period, field crews visit each monitoring location to retrieve data, verify proper monitor operation, and document field conditions. The following quality assurance steps are taken to assure the integrity of the data collected:

- **Measure Power Supply:** The monitor is powered by a dry cell battery pack. Power levels are recorded and battery packs replaced, if necessary. A separate battery

provides back-up power to memory, which allows the primary battery to be replaced without the loss of data.

- **Perform Pipe Line Confirmations and Confirm Depth and Velocity:** Once equipment and sensor installation is accomplished, a member of the field crew descends into the manhole to perform a field measurement of flow rate, depth and velocity to confirm they are in agreement with the monitor. Since the ADS V-3 velocity sensor measures peak velocity in the wetted cross-sectional area of flow, velocity profiles are also taken to develop a relationship between peak and average velocity in lines that meet the hydraulic criteria.

- **Measure Silt Level:** During site confirmation, a member of the field crew descends into the manhole and measures and records the depth of silt at the bottom of the pipe. This data is used to compute the true area of flow.

- **Confirm Monitor Synchronization:** The field crew checks the flow monitor's clock for accuracy.

- **Upload and Review Data:** Data collected by the monitor is uploaded and reviewed for comparison with previous data. All readings are checked for consistency and screened for deviations in the flow patterns, which indicate system anomalies or equipment failure.

CHAPTER 3 Data Analysis and Presentation

3.1 Data Analysis

A flow monitor is programmed to collect data at 15-minute intervals throughout the monitoring period. The monitor stores raw data consisting of (1) the air range (distance from sensor to top of flow) for each active ultrasonic depth sensor pair and (2) the peak velocity. If the monitor is equipped with a pressure sensor, then a depth reading from this sensor may also be stored. When the field personnel collect the data, the air range is converted to depth data based on the pipe height and physical offset (distance from the top of the pipe to the surface of the ultrasonic sensor). The data is imported into ADS's proprietary software and is examined by a data analyst to verify its integrity. The data analyst also reviews the daily field reports and site visit records to identify conditions that would affect the collected data.

Velocity profiles and line confirmation data developed by the field personnel are reviewed by the data analyst to identify inconsistencies and verify data integrity. Velocity profiles are reviewed and an average to peak velocity ratio is calculated for the site. This ratio is used in converting the peak velocity measured by the sensor to the average velocity used in the Continuity equation. A hydraulic coefficient (HC) is calculated from the data for each line confirmation. This hydraulic coefficient is the ratio of the coefficients s and n, previously discussed in the presentation of Manning's equation (section 2.1.2).

The data analyst selects which ultrasonic pairs and/or depth sensor entity will be used to calculate the final depth information. Silt levels present at each site visit are reviewed and representative silt levels established.

Selections for the above parameters can be constant or can change during the monitoring period. While the data analysis process is described in a linear manner, it often requires an iterative approach to accurately complete.

3.2 Data Presentation

This type of flow monitoring project generates a large volume of data. To facilitate review of the data, results have been provided in graphical and tabular formats. The flow data is presented graphically in the form of scattergraphs and hydrographs. Tables are provided in daily and 15-minute averages. These tables show the flow rate for each day, along with the daily minimum and maximums, the times they were observed, the total daily flow, and total flow for the month (or monitoring period). The following explanation of terms may aid in interpretation of the tables and hydrographs:

AMMIN FLW -- The MIN FLOW observed during the a.m. hours (in MGD)

DFINAL – Final calculated depth measurement (in inches)

HYDRAULIC COEFF (HC) -- Confirm factor for use in the Manning equation

MAX FLOW -- The maximum observed flow rate during the reporting period (in MGD)

MIN FLOW -- The minimum observed flow rate during the reporting period (in MGD)

QFINAL -- Final calculated flow rate (in MGD)

VFINAL – Final calculated flow velocity (in feet per second)

TOT FLOW -- Total volume of flow recorded for the indicated time period (in MG)

RAIN—Total rainfall received during reporting interval.

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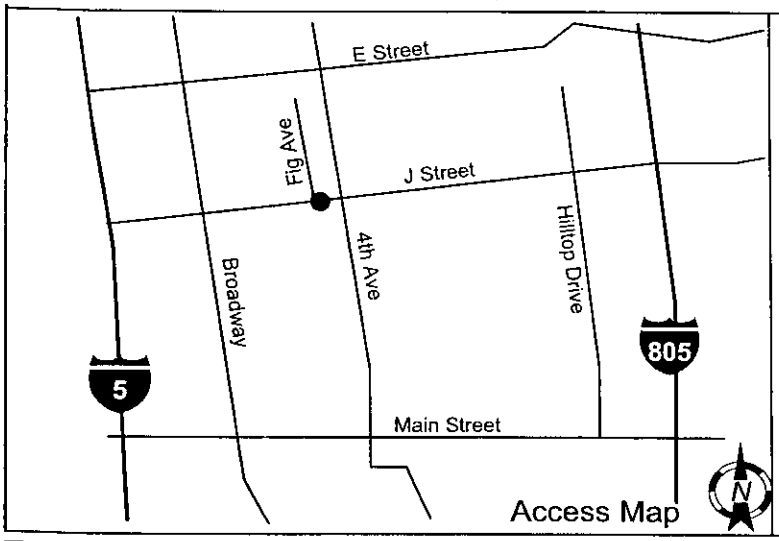
Site Report

FM Initials: NV

Project Name: Chula Vista, CA.

Site Name:	CV1	Monitor Series:	1502	Monitor S/N:	9474	**Manhole #**	3947
Address / Location:	435 J Street between Fig and 4th Avenue.			**Thomas Bros Map Page:**		1330-B1	
				Pipe Height:		12.13 "	
Access:	Drive	Type of System:	**Sanitary**	**Pipe Width:**		12.00 "	
				Phone Number:			



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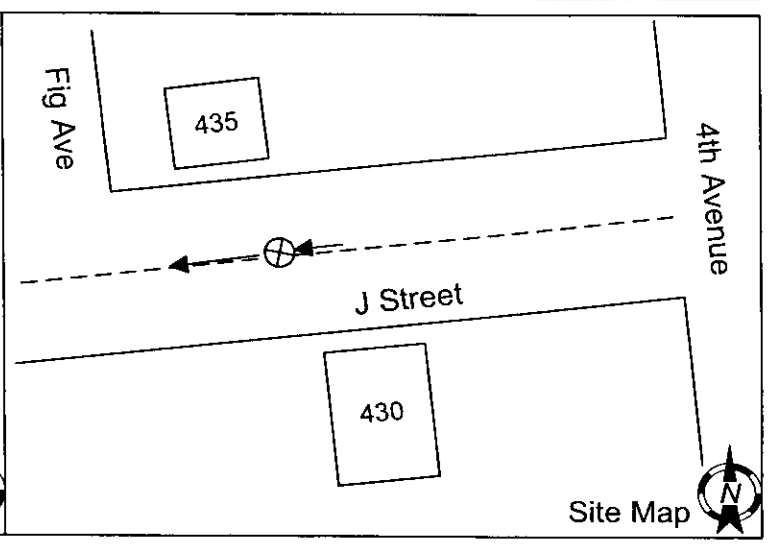


Site Map

Investigation Information

Time of Investigation:	05/13/03	0800
Site Hydraulics:	Low, slow flow conditions straight through pipe. No visible backup or surcharge.	
Upstream Input: (L/S, P/S)		
Upstream Manhole:		
Downstream Manhole:		
Depth of Flow:	1.38" +/- .13"	
Range (Air DOF):	+/-	
Peak Velocity:	1.89 fps	
Silt:	0.00 Inches	

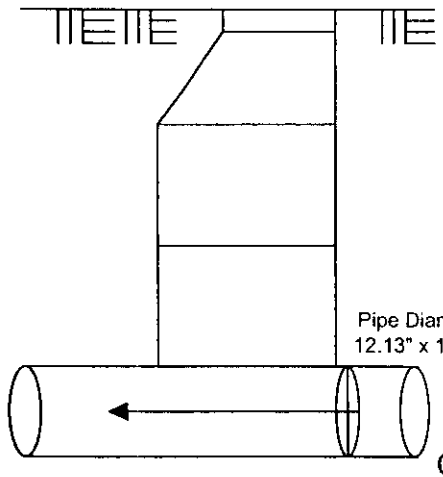
Manhole Information:

Manhole Depth:	5.8 Feet	
Manhole Material / Condition	Pre-cast	Good
Active Drop Connections?	No	
Pipe Material / Condition:	VCP	Good
Mini System Character:	Commercial / Industrial / **Residential** / Other	

Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



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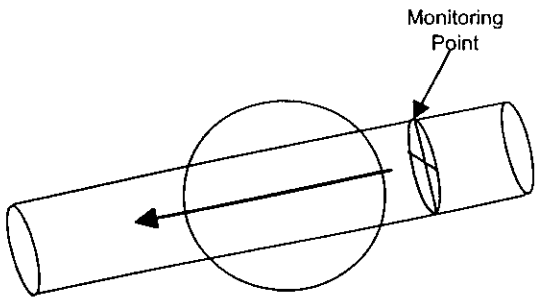


Planar

Installation Information		Backup	Yes	No	?	Distance
Installation Type:	Regular	Trunk				
Sensors Devices:	Ultrasonic, Pressure and Velocity sensors	Lift / Pump Station				
Surcharge Height:		WWTP				
Rain Gauge Zone:		Other				

Additional Site Information / Comments:

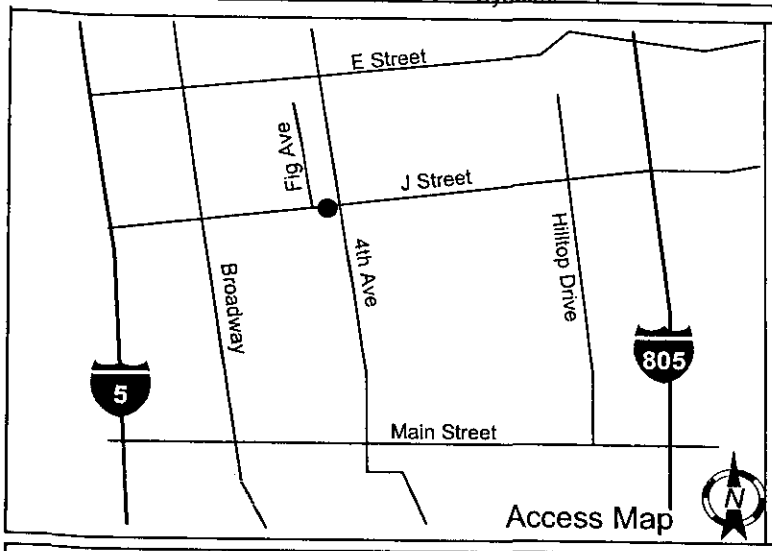
ADS ENVIRONMENTAL SERVICES
a division of ADS Corporation

Site Report

FM Initials: NV

Project Name: Chula Vista, CA.

Site Name:	CV2	Monitor Series:	1502	Monitor S/N:	9490	**Manhole #**	3938
Address / Location:	428 J Street between Fig and 4th Avenue.			**Thomas Bros Map Page:**		1330-B1	
Access:	Drive	Type of System:	**Sanitary**	**Pipe Height:**		17.88 "	
				Pipe Width:		17.88 "	
				Phone Number:			



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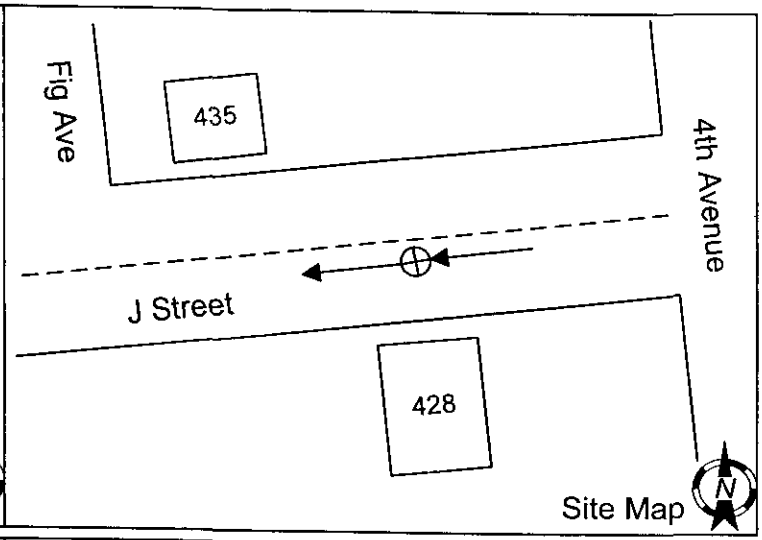


Site Map

Investigation Information

Date/Time of Investigation:	05/13/03	0800
Site Hydraulics:	Swift flow with some turbulence straight through pipe. No visible backup or surcharge.	
Upstream Input: (L/S, P/S)		
Upstream Manhole:		
Downstream Manhole:		
Depth of Flow:	6.50" +/- .25"	
Range (Air DOF):	+/-	
Peak Velocity:	9.08 fps	
Silt:	0.00 Inches	

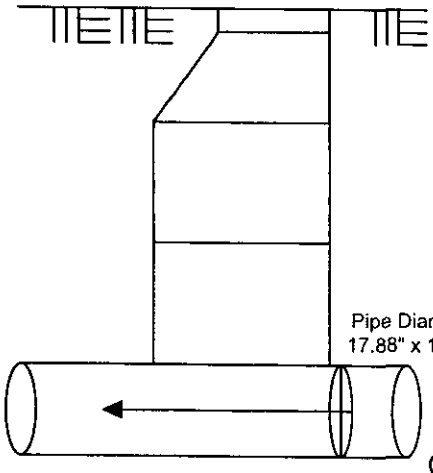
Manhole Information:

Manhole Depth:	6.1 Feet	
Manhole Material / Condition	Pre-cast	Fair
Active Drop Connections?	No	
Pipe Material / Condition:	VCP	Good
Mini System Character:	Commercial / Industrial / **Residential** / Othe	

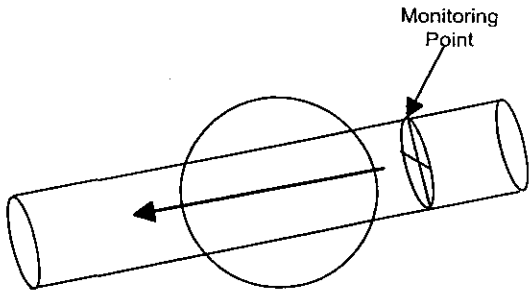
Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



Cross Section



Planar

Installation Information		Backup	Yes	No	?	Distance
Installation Type:	Regular	Trunk				
Sensors Devices:	Ultrasonic, Pressure and Velocity sensors	Lift / Pump Station				
Surcharge Height:		WWTP				
Rain Gauge Zone:		Other				

Additional Site Information / Comments:

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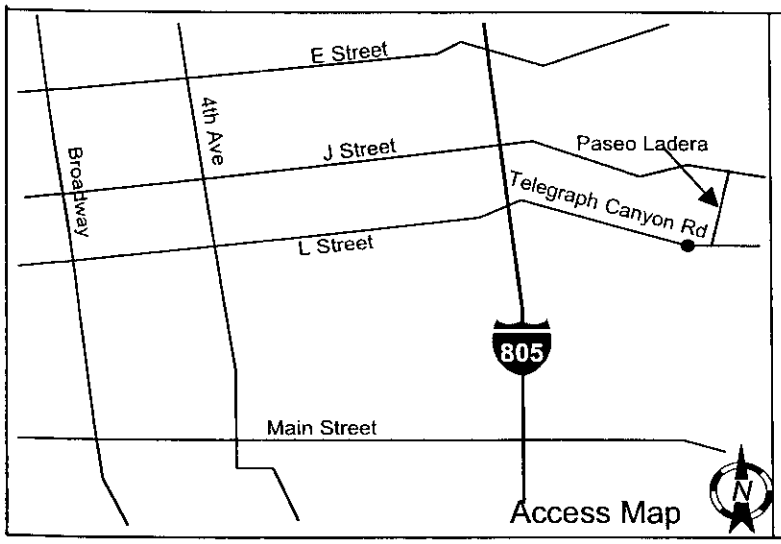
a division of ADS Corporation

Site Report

FM Initials: NV
Project Name: Chula Vista, CA.

Site Name:	CV3	Monitor Series:	1502	Monitor S/N:	9674	**Manhole #**	75
Address / Location:	Telegraph Canyon Road. 100 yds West of Paseo Ladera			**Thomas Bros Map Page:**		1330-J1	
				Pipe Height:		20.75 "	
Access:	Drive	Type of System:	**Sanitary**	**Pipe Width:**		20.75 "	
				Phone Number:			



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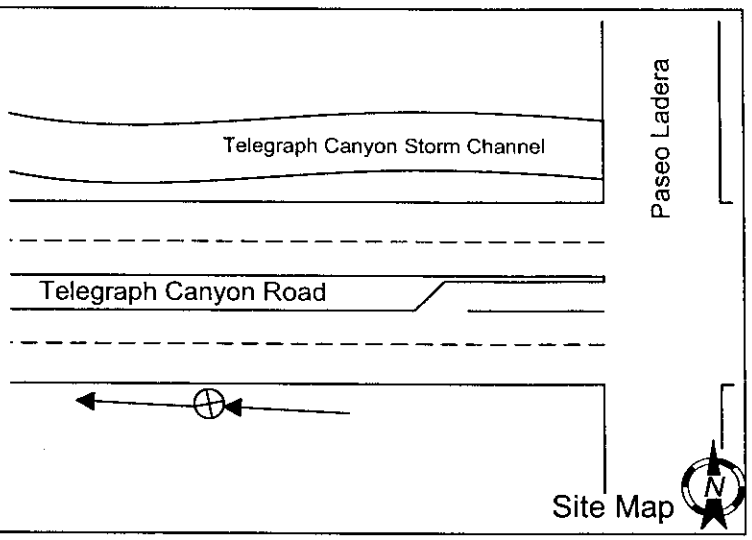


Site Map

Investigation Information

Date / Time of Investigation:	05/13/03	0800
Site Hydraulics:	Fast, smooth flow conditions straight through pipe. No visible backup or surcharge.	
Upstream Input: (L/S, P/S)		
Upstream Manhole:		
Downstream Manhole:		
Depth of Flow:	5.25" +/- .25"	
Range (Air DOF):	+/-	
Peak Velocity:	8.07 fps	
Silt:	0.00 Inches	

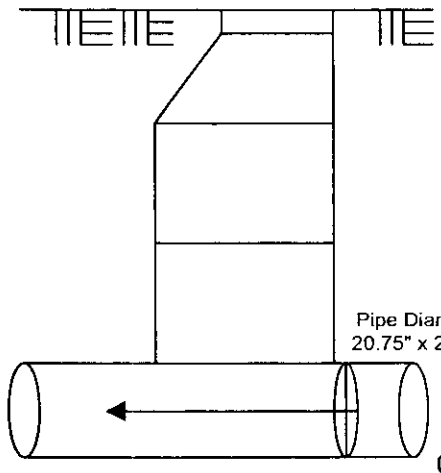
Manhole Information:

Manhole Depth:	12.6 Feet	
Manhole Material / Condition	Lined Pre-cast	Good
Active Drop Connections?	No	
Pipe Material / Condition:	PVC	Good
Mini System Character:	Commercial / Industrial / **Residential** / Other	

Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



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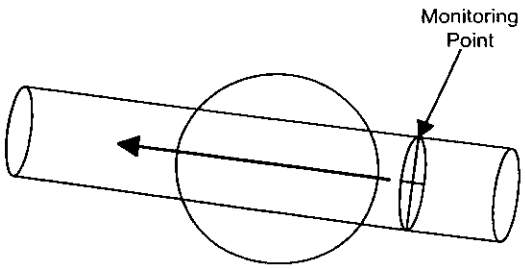

Planar

Installation Information		Backup	Yes	No	?	Distance
Installation Type:	Regular	Trunk				
Sensors Devices:	Ultrasonic, Pressure and Velocity sensors	Lift / Pump Station				
Surcharge Height:		WWTP				
Rain Gauge Zone:		Other				

Additional Site Information / Comments:

ADS ENVIRONMENTAL SERVICES
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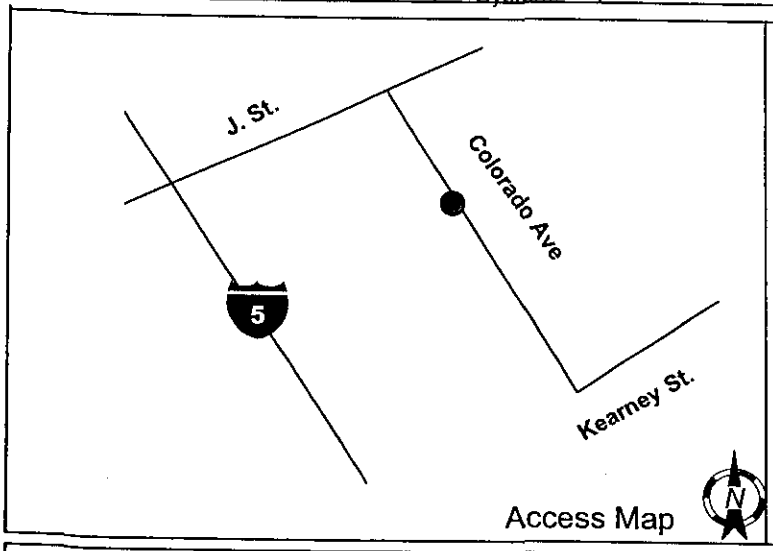
Site Report

FM Initials: NV

Project Name: Chula Vista, CA.

Site Name:	CV4	Monitor Series:	1502	Monitor S/N:	9428	**Manhole #**	4243
Address / Location:	726 Colorado Ave. 6' off of west curb			**Thomas Bros Map Page:**		1330-A2	
Access:	Drive	Type of System:	**Sanitary**	**Pipe Height:**		15.50 "	
				Pipe Width:		15.75 "	
				Phone Number:			



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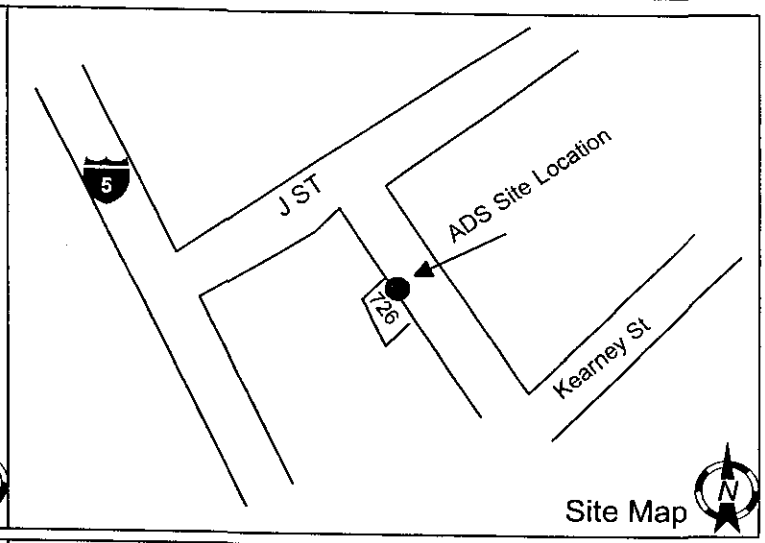


Site Map

Investigation Information

Date/Time of Investigation:	05/13/03	11:30
Site Hydraulics:	Good, smooth flow conditions straight through	
Upstream Input: (L/S, P/S)		
Upstream Manhole:		
Downstream Manhole:		
Depth of Flow:	9.75" +/- .25"	
Range (Air DOF):	+/-	
Peak Velocity:	3.28 fps	
Silt:	0.00 Inches	

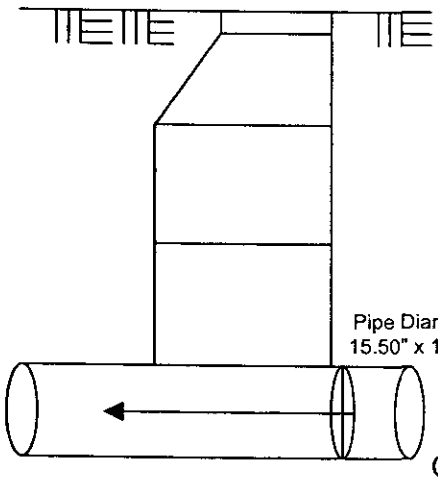
Manhole Information:

Manhole Depth:	10 Feet	
Manhole Material / Condition	Lined Pre-cast	Good
Active Drop Connections?	No	
Pipe Material / Condition:	PVC	Good
Mini System Character:	Commercial / Industrial / **Residential** / Othe	

Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



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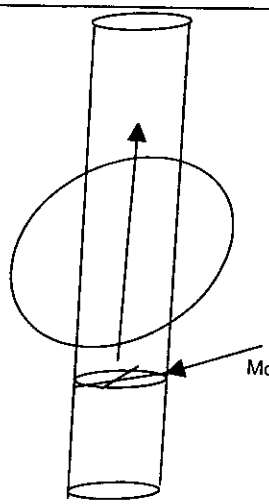

Planar

Installation Information		Backup	Yes	No	?	Distance
Installation Type:	Regular	Trunk				
Sensors Devices:	Ultrasonic, Pressure and Velocity sensors	Lift / Pump Station				
Surcharge Height:		WWTP				
Rain Gauge Zone:		Other				

Additional Site Information / Comments:

ADS ENVIRONMENTAL SERVICES
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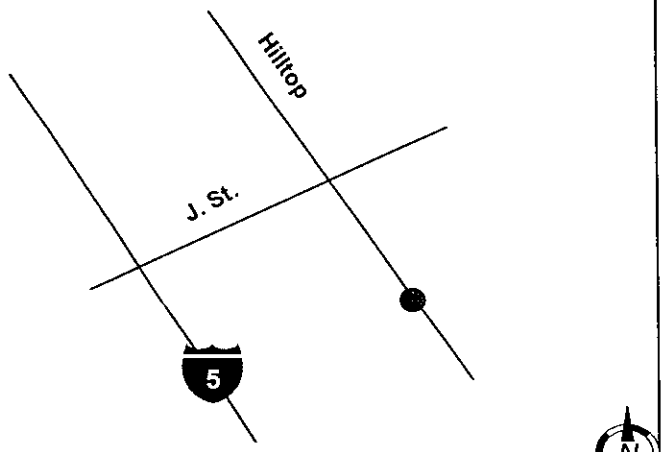
Site Report

FM Initials: NV

Project Name: Chula Vista, CA.

e Name:	CV5	Monitor Series:	1502	Monitor S/N:	9069	Manhole #	3495
Address / Location:	726 Hilltop in center of road			Thomas Bros Map Page:		1330-D-7	
				Pipe Height:		21.25 "	
Access:	Drive	Type of System:	Sanitary	Pipe Width:		21.25 "	
				Phone Number:			



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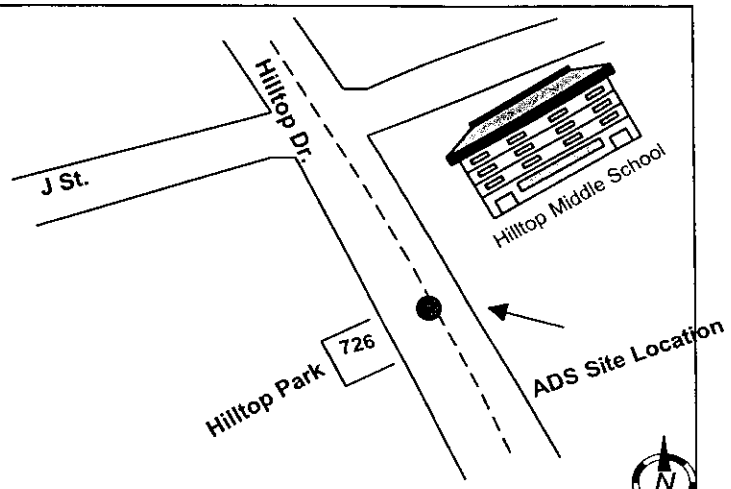


Site Map

Investigation Information

Da	ne of Investigation:	5-13-2003	9:00
	ite Hydraulics:	Fast, smooth flow conditions straight	
	ream Input: (L/S, P/S)		
	stream Manhole:		
	Downstream Manhole:		
	Depth of Flow:	11.38"	+/- .25"
	Range (Air DOF):		+/-
	Peak Velocity:	4.60	fps
	Silt:	0.00	Inches

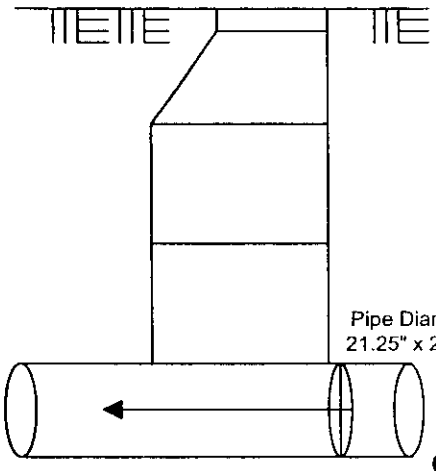
Manhole Information:

Manhole Depth:	14 Feet	
Manhole Material / Condition	Lined Pre-cast	Good
Active Drop Connections?	No	
Pipe Material / Condition:	PVC	Good
Mini System Character:	Commercial / Industrial / **Residential** / Other	

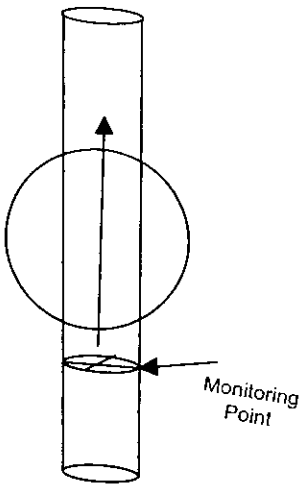
Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



Cross Section



Planar

Installation Information		Backup	Yes	No	?	Distance
tallation Type:	Regular	Trunk				
ensors Devices:	Ultrasonic, Pressure and Velocity sensors	Lift / Pump Station				
Surcharge Height:		WWTP				
Rain Gauge Zone:		Other				

Additional Site Information / Comments: Very Little to no flow coming from side connect

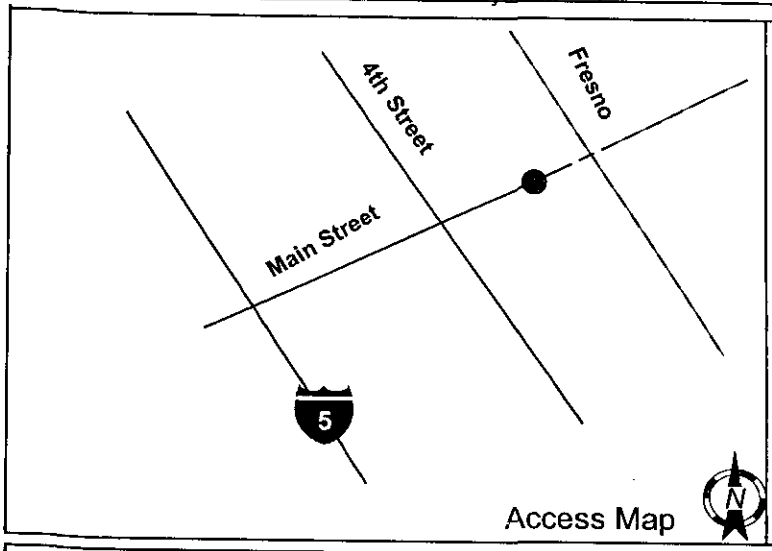
ADS ENVIRONMENTAL SERVICES
a division of ADS Corporation

Site Report

FM Initials: NV

Project Name: Chula Vista, CA.

Site Name:	CV6	Monitor Series:	1502	Monitor S/N:	9918	Manhole #	5122
Address / Location:	3050 Main St. on north side of median			Thomas Bros Map Page:		1330-D-5	
Access:	Drive	Type of System:	Sanitary	Pipe Height:		15.13 "	
				Pipe Width:		15.13 "	
				Phone Number:			



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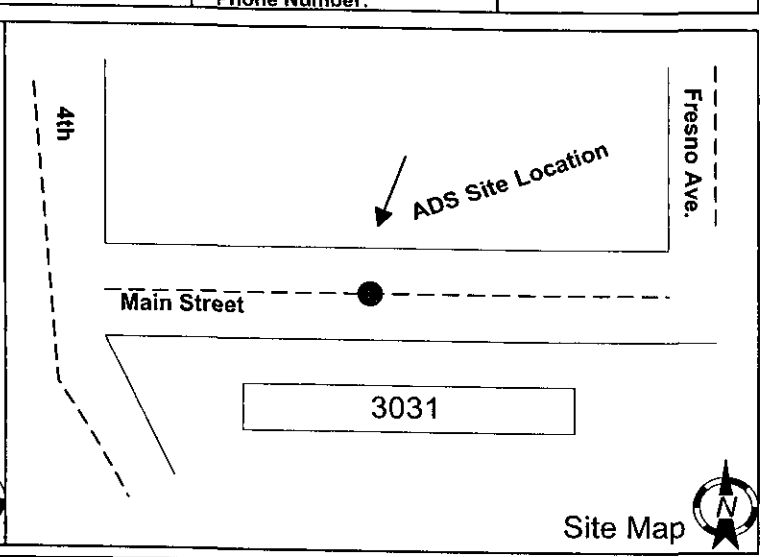


Site Map

Investigation Information

Date/Time of Investigation:	5-13-2003	14.30	
Site Hydraulics:	Smooth flow conditions straight through		
Upstream Input: (L/S, P/S)			
Upstream Manhole:			
Downstream Manhole:			
Depth of Flow:	7.13"	+/-	.25"
Range (Air DOF):		+/-	
Peak Velocity:	7.30	fps	
Silt:	0.00	Inches	

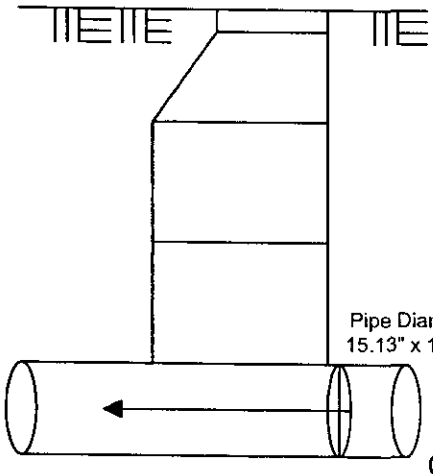
Manhole Information:

Manhole Depth:	9.4 Feet	
Manhole Material / Condition	Lined Pre-cast	Good
Active Drop Connections?	No	
Pipe Material / Condition:	PVC	Good
Mini System Character:	Commercial / Industrial / **Residential** / Other	

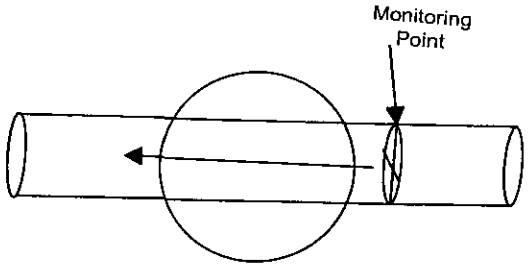
Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



Cross Section



Planar

Installation Information

Installation Type:	Regular
Sensors Devices:	Ultrasonic, Pressure and Velocity sensors
Surcharge Height:	
Rain Gauge Zone:	

Backup	Yes	No	?	Distance
Trunk				
Lift / Pump Station				
WWTP				
Other				

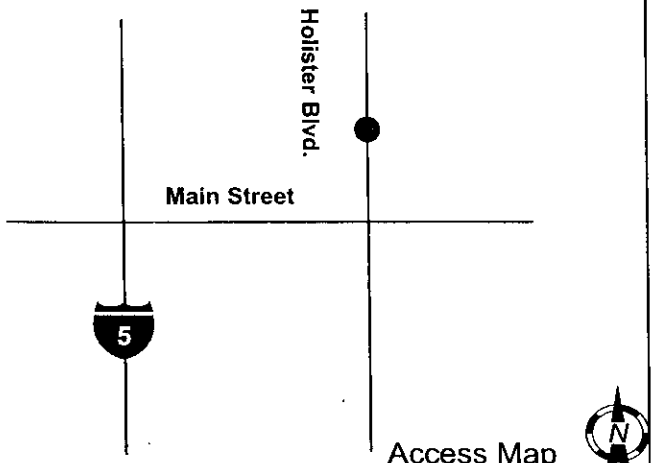
Additional Site Information

ADS ENVIRONMENTAL SERVICES
a division of ADS Corporation

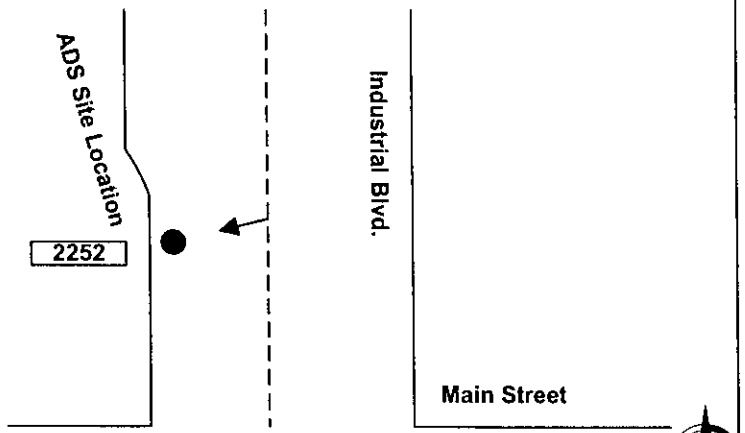
Site Report

FM Initials: NV
Project Name: Chula Vista, CA.

e Name:	CV7	Monitor Series:	1502	Monitor S/N:	9969	Manhole #	5079
Address / Location:	2292 Industrial Blvd. at west curb.			Thomas Bros Map Page:		1330-D5	
				Pipe Height:		12.00 "	
Access:	Drive	Type of System:	Sanitary	Pipe Width:		12.00 "	
				Phone Number:			



Access Map



Site Map

Investigation Information

Da	e of Investigation:	5-13-2003	13.30
	ite Hydraulics:	Fast, smooth flow conditions straight	
	tream Input: (L/S, P/S)		
	stream Manhole:		
	Downstream Manhole:		
	Depth of Flow:	4.88" +/- .25"	
	Range (Air DOF):	+/-	
	Peak Velocity:	8.30 fps	
	Silt:	0.00 Inches	

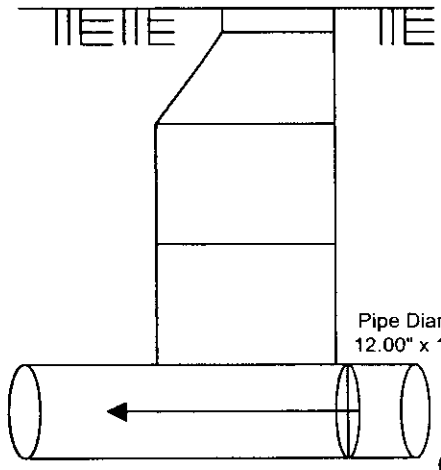
Manhole Information:

Manhole Depth:	8.4 Feet	
Manhole Material / Condition	Lined Pre-cast	Fair
Active Drop Connections?	No	
Pipe Material / Condition:	PVC	Good
Mini System Character:	Commercial / Industrial / **Residential** / Other	

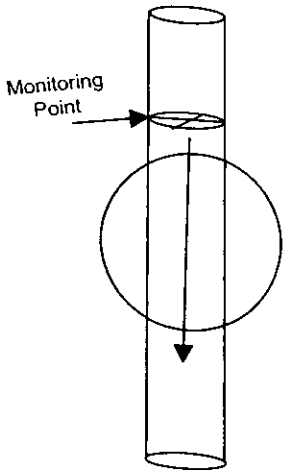
Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



Cross Section



Planar

Installation Information		Backup	Yes	No	?	Distance
tallation Type:	Regular	Trunk				
ensors Devices:	Ultrasonic, Pressure and Velocity sensors	Lift / Pump Station				
Surcharge Height:		WWTP				
Rain Gauge Zone:		Other				

Additional Site Information

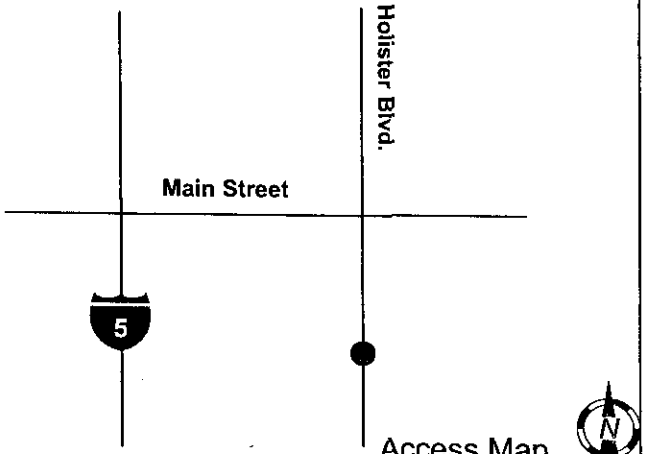
ADS ENVIRONMENTAL SERVICES
a division of ADS Corporation

Site Report

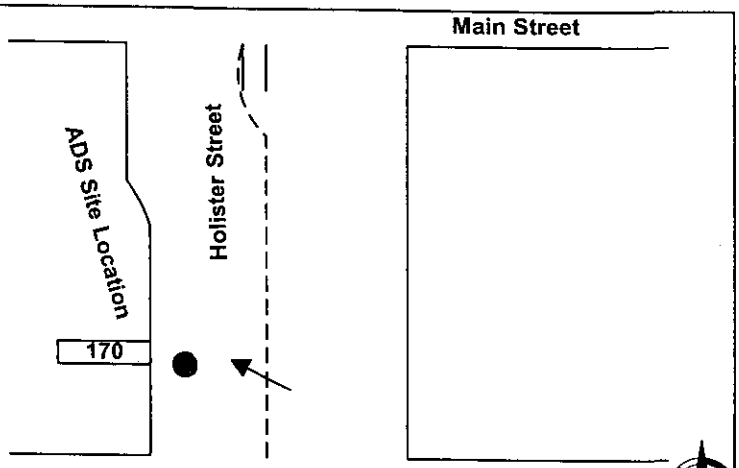
FM Initials: NV

Project Name: Chula Vista, CA.

Site Name:	CV8	Monitor Series:	1502	Monitor S/N:	9894	Manhole #	5144
Address / Location:	170 Hollister St. south of Main St. at Manya St.			Thomas Bros Map Page:		1330-B5	
				Pipe Height:		17.75 "	
Access:	Drive	Type of System:	Sanitary	Pipe Width:		17.75 "	
				Phone Number:			



Access Map



Site Map

Investigation Information

Date/Time of Investigation:	5-13-2003	14:00	
Site Hydraulics:	Smooth flow conditions straight		
Upstream Input: (L/S, P/S)			
Upstream Manhole:			
Downstream Manhole:			
Depth of Flow:	4.88"	+/-	.25"
Range (Air DOF):		+/-	
Peak Velocity:	4.78	fps	
Silt:	0.00	Inches	

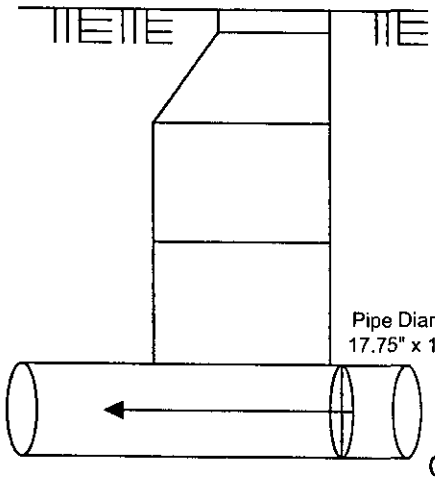
Manhole Information:

Manhole Depth:	9.1 Feet	
Manhole Material / Condition	Lined Pre-cast	Fa
Active Drop Connections?	No	
Pipe Material / Condition:	PVC	Good
Mini System Character:	Commercial / Industrial / **Residential** / Othe	

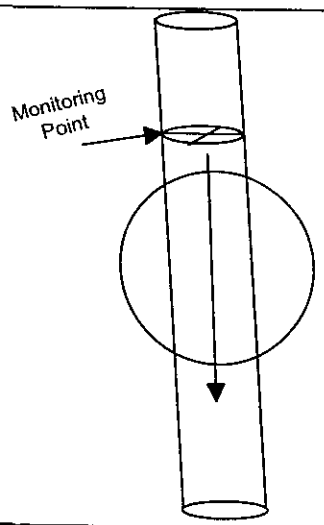
Telephone Information:

Access Pole #:	
Distance From Manhole:	Feet
Road Cut Length:	Feet
Trench Length:	Feet

Other Information:



Cross Section



Planar

Installation Information		Backup	Yes	No	?	Distance
Installation Type:	Regular	Trunk				
Sensors Devices:	Ultrasonic, Pressure and Velocity sensors	Lift / Pump Station				
Surcharge Height:		WWTP				
Rain Gauge Zone:		Other				

Additional Site Information